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Selective Predation by Noturus insignis (Richardson) (Teleostei: Ictaluridae) in the Delaware River

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ABSTRACT.—Stomach contents of 403 margined madtoms *Noturus insignis* (Richardson), collected several times throughout 1988 and 1989 were examined. Insects in the families Baetidae, Chironomidae and Simuliidae, all of which have nocturnal drift patterns, were present in stomach samples in proportions higher than those in the environment. Margined madtoms showed an activity peak (inferred from capture efficiency) at midnight in both years. Usually feeding began at dusk and its rate increased until 0400 h, as suggested by changes in stomach fullness over 24 h. Diel feeding periodicity was similar to that exhibited by other *Noturus* species. During 2 of the 4 samples days on which sizes of prey in the environment were compared to sizes in the diet, margined madtoms consumed organisms that were smaller, on average, than those collected from the substrate. On the other 2 days, the diet samples and environmental samples were not significantly different. Margined madtoms ate insects that were most active and most available between midnight and dawn.

INTRODUCTION

Noturus insignis, the margined madtom, is native to many Atlantic slope streams from Georgia to New York, parts of the Lake Ontario drainage and the upper Kanawha River system (Taylor, 1969; Rohde, 1980). Accidental introductions are presumably responsible for its occurrence in the upper Ohio River drainage, the Tennessee River system and the Merrimack River in New Hampshire (Taylor, 1969). The margined madtom is usually found in clear streams with moderate current and abundant gravel and rubble (Rohde, 1980). Margined madtoms live as long as 4 yr; females become sexually mature in their 3rd summer, whereas males mature a year earlier (Clugston and Cooper, 1960). Most growth occurs in July, August and September, after spawning has occurred.

Bowman (1932) found that the stomachs of *Noturus* [*Rabida*] *insignis* collected during daylight hours were nearly empty or contained highly digested food items, whereas the stomachs of specimens collected at 0100 h contained relatively undigested prey items, implying nocturnal feeding. Through stomach content analysis, Bowman (1936) surmised that *N. insignis* feeds almost exclusively on aquatic insect larvae. Bowman did not systematically compare the relative abundances of prey items in the madtoms' diet to their relative abundances in the environment.

Many have studied the feeding behavior of madtoms. Mayden and Burr (1981) speculated that since *Noturus exilis* Nelson is primarily a nocturnal species it feeds principally by taste (as observed in aquaria) rather than by sight. They made no direct comparisons, but noted chironomids appeared most abundant in *N. exilis* when chironomids were at their peak drift. Robison and Harp (1985) found that *N. lachneri* Taylor began feeding between 20–90 min after sunset. Page and Smith (1971) reported that the riffle fishes *Percina phoxcephala* (Nelson) and *P. sciera* (Swain) fed on whatever food was available and palatable and that feeding patterns closely followed insect population cycles. Likewise, Starnes and Starnes (1985) found that gut contents of *N. eleutherus* Jordan shifted with the most abundant benthic taxa, most commonly baetids and chironomids. They speculated that since baetids and chironomids are nocturnally active their availability to madtoms might be increased.

The objectives of our study were to determine—if a population of margined madtoms in the Delaware River—(1) selectively feed on particular sizes or taxa of prey, (2) show diel periodicity in feeding habitats, and/or (3) show ontogenetic diet variation.

Study Site

Nine collections were made in the Delaware River in Wayne County, PA, near Narrowsburg, N.Y., during 1988 and 1989. At this site, the river is approximately 150 m wide and includes a 250 m reach of riffle habitat. Substrates were mostly gravel and rubble in the riffle area; predominant substrates in pools were mud and silt. The banks were wooded with large, gently sloping riparian areas. River depth in the area sampled ranged seasonally from 0.25 m to 1.0 m. During winters the river froze over completely and was not sampled.

Materials and Methods

Margined madtoms were collected with a 1.5 × 3.0 m, 3.2-mm mesh seine after dusk for approximately 2 h on nine dates between 2 May 1988 and 23 August 1989. To study feeding chronology, collections were made for 20 min every 2 h for 24 h on 27–28 June 1988 and 10–11 July 1989. All madtoms were immediately immersed in a quinaldine solution (to prevent regurgitation of food) for 5–10 min and were subsequently placed in a 10% formalin solution for several days. Specimens were transferred to 50% isopropyl alcohol and deposited in The Pennsylvania State University Fish Museum.

Standard length (SL), total length (TL) and head length (HL) of each preserved madtom were measured to the nearest 0.1 mm using dial calipers (Hubbs and Lagler, 1958). Stomach contents were identified and measured under a stereomicroscope to the lowest possible taxon, assigned to 1-mm length classes (excluding antennae and tails) using a grid placed beneath the specimens, and enumerated.

Prior to each fish collection, benthic samples were collected with a D-frame kick net as described by Frost *et al.* (1970). The substrate was disturbed directly upstream of the net; nine randomly chosen samples (20 sec each) were taken and pooled. Macroinvertebrates were fixed in 50% isopropyl alcohol with a small amount of formalin and were identified to the lowest practical taxon using Pennak (1978), Merrit and Cummins (1984) and Wiggins (1977). Benthic macroinvertebrates from four collections were assigned to 1-mm size classes. These samples were compared to stomach sample collections to determine size selectivity.

To gather information on the drift patterns of aquatic insects, drift samples were collected on 10–11 July 1989 every 2 h using a trio of drift nets (150-mm diam, 45-micron mesh). Stream velocity was measured with a Marsh-McBirney model 201d current meter at the mouth of the nets to quantify drift volume sampled.

A likelihood G test was used to determine whether the distribution of taxa in the madtom stomachs was different from the distribution of taxa from the benthos. Prey size distributions were compared for three size classes of madtoms. A Kolmogorov-Smirnov test was used to determine whether large madtoms ate larger prey than small madtoms. This test also compared the size distribution of prey consumed by madtoms with the size distribution of the benthic prey collected on four dates in different seasons. Alpha was set a priori at 0.05 for all statistical tests.

Results

Fishes commonly collected in riffles with *Noturus insignis* included *Petromyzon marinus* Linnaeus, *Anguilla rostrata* (LeSueur), *Campostoma anomalum* (Rafinesque), *Exoglossum maxillingua* (LeSueur), *Rhinichthys atratulus* (Hermann), *R. cataractae* (Valenciennes), *Semotilus corporalis* (Mitchill), *Hypentelium nigricans* (LeSueur), *Micropterus dolomieui* Lacepede, *Etheostoma olmstedi* Storer and *Percina peltata* (Stauffer). No other species of madtoms

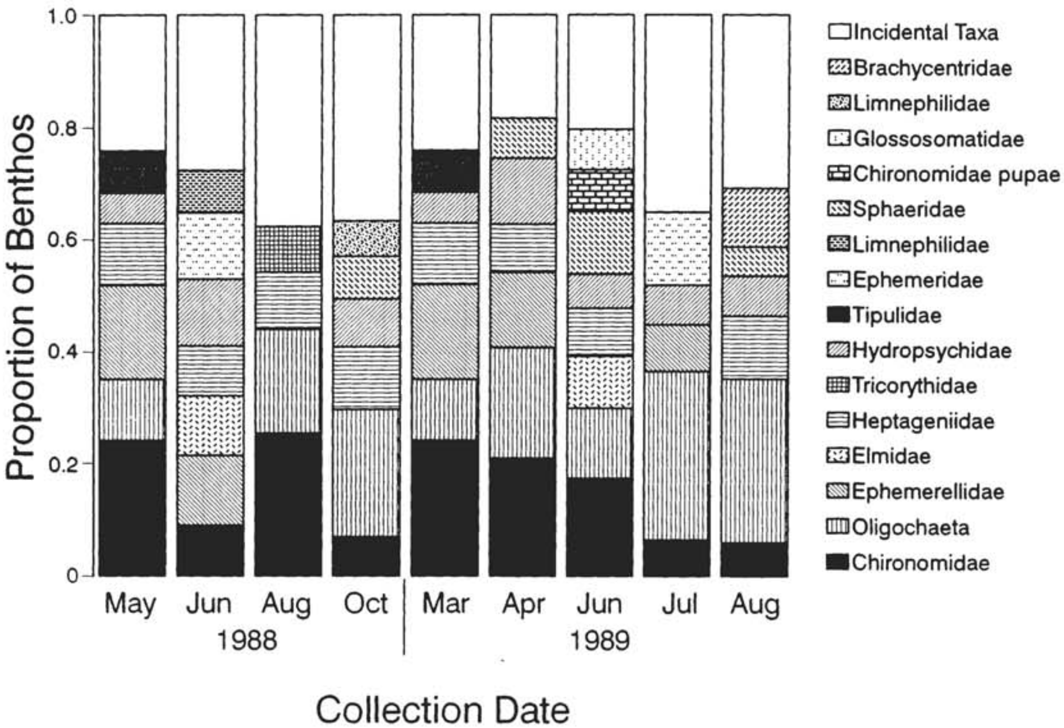

FIG. 1.—Plot of taxa proportions collected from the benthos on each sampling day. Incidental taxa represents the pooled proportions of taxa that did not comprise at least 6% of a sample on at least 1 day

has been found in the upper Delaware River, though *N. gyrinus* has been collected historically in the lower Delaware drainage in extreme southeastern Pennsylvania (Cooper, 1983).

Selective predation by taxon.—Oligochaete worms, ephemerellid mayflies, chironomid larvae, heptageniid mayflies and hydropsychid caddisflies, collectively, represented at least 50% of the individuals inhabiting the benthos (Fig. 1). The most common ephemerellids were *Ephemerella* and *Serratella,* and the most numerous heptageniids were *Leucrocuta* and *Stenonema. Hydropsyche* and *Cheumatopsyche* constituted the bulk of the hydropsychids. Neither oligochaetes nor chironomids were identified to genus.

Oligochaetes were rarely eaten by *Noturus insignis* (Fig. 2) although they were often abundant in the benthos (Fig. 1). In contrast, chironomids consistently comprised more than 50% of the prey items in the stomachs. Baetids and ephemerellids were also found in high proportions in the stomachs, though not simultaneously. Simuliids constituted as much as 10% of the madtom diet, although their proportion in the benthos never exceeded 1%.

The distribution of taxa in the diet of madtoms was different from the distribution of taxa in the benthos for each of the nine collections (G-test, $P < 0.05$). Chironomids, baetids and simuliids were consistently eaten in higher proportions than they were found in the environment (Figs. 1 and 2).

Selective predation by prey size.—The cumulative frequency of prey size classes available in the benthos was compared to that of prey taken from madtom stomachs to determine whether the madtoms were eating prey in the same size proportions as were found in the benthos. Dietary size frequencies were significantly ($P < 0.05$) smaller than available size

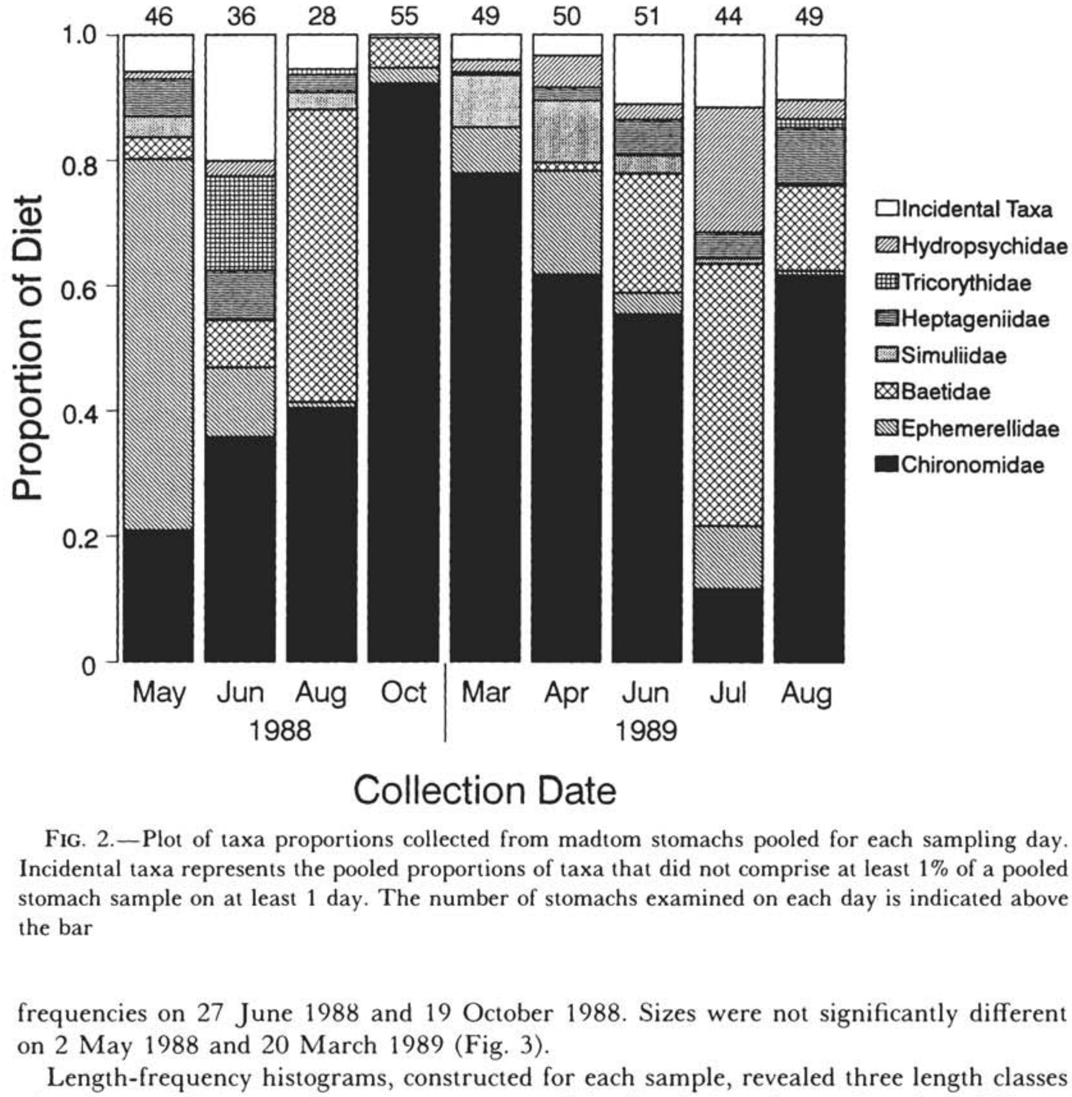

FIG. 2.—Plot of taxa proportions collected from madtom stomachs pooled for each sampling day. Incidental taxa represents the pooled proportions of taxa that did not comprise at least 1% of a pooled stomach sample on at least 1 day. The number of stomachs examined on each day is indicated above the bar

frequencies on 27 June 1988 and 19 October 1988. Sizes were not significantly different on 2 May 1988 and 20 March 1989 (Fig. 3).

Length-frequency histograms, constructed for each sample, revealed three length classes of madtoms. Distinct madtom size groups could be discriminated on 4 days in 3 different seasons (Table 1). Small fish consistently consumed smaller prey than did medium and large madtoms. On two of the four sampling dates, 19 October 1988 and 28 April 1989, the consumption patterns of medium and large fish differed significantly ($P > 0.05$) from each other.

Diel periodicity.—On 27–28 June 1988, catches peaked at 0000 h, fell to zero at 0200 h, increased somewhat at 0400 h and then returned to zero at 0600 h, where they remained until 1600 h (Fig. 4). Catches were high throughout the entire night on 10–11 July 1989 (2200 to 0400 h) and fell to low levels during the day (Fig. 4). As on 27–28 June 1988, catches were highest at 0000 h.

Diel feeding patterns of madtoms were similar to their activity patterns. On 27–28 June 1988, stomachs were empty from 1800 h to 2000 h, the numbers of ingested organisms increasing thereafter to a peak at 0000 h (Fig. 5). On 10–11 July 1989, a similar pattern was seen; the number of organisms peaked at 0400 h and then fell indicating a slow-down or complete cessation of feeding (Fig. 5). Feeding periodicity of madtoms, as evidenced by

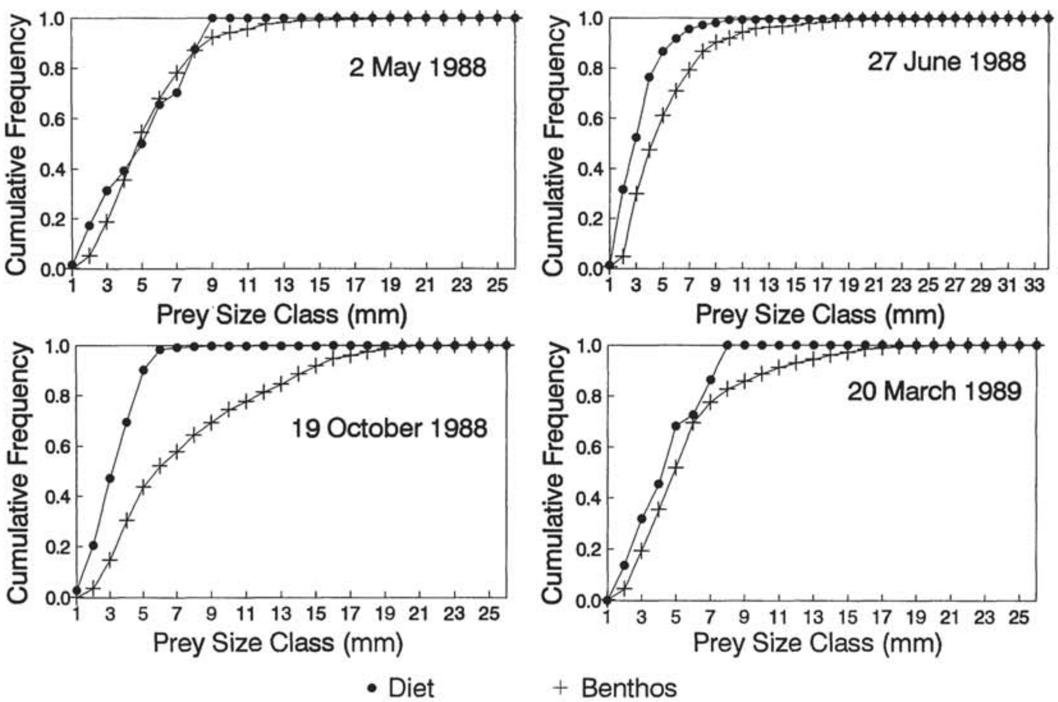

FIG. 3.—Cumulative frequency of macroinvertebrates taken from madtom stomachs and substrate plotted against prey size class for the four collection dates. Prey were placed in 1-mm size classes

activity (Fig. 4), closely reflects diel variation in macroinvertebrate drift (Fig. 6). Prey items were found in madtom stomachs at the same time the macroinvertebrates were drifting (Fig. 5). Abundances of chironomid larvae remained constant throughout the 24-h study (Fig. 6).

DISCUSSION

Most feeding studies of madtoms have concentrated on the stomach contents without determining the availabilities of potential prey taxa in the environment. The only madtom

TABLE 1.—Size ranges for madtom groups among which prey item size was compared

Date	Size	Size range	Sample size
27 June 1988	small	36–51	17
	medium	54–69	7
	large	72–87	2
19 October 1988	small	27–45	34
	medium	48–66	17
	large	69–75	4
28 April 1989	small	33–51	24
	medium	51–69	12
	large	69–90	14
23 August 1989	small	27–42	34
	medium	51–69	11
	large	72–89	3

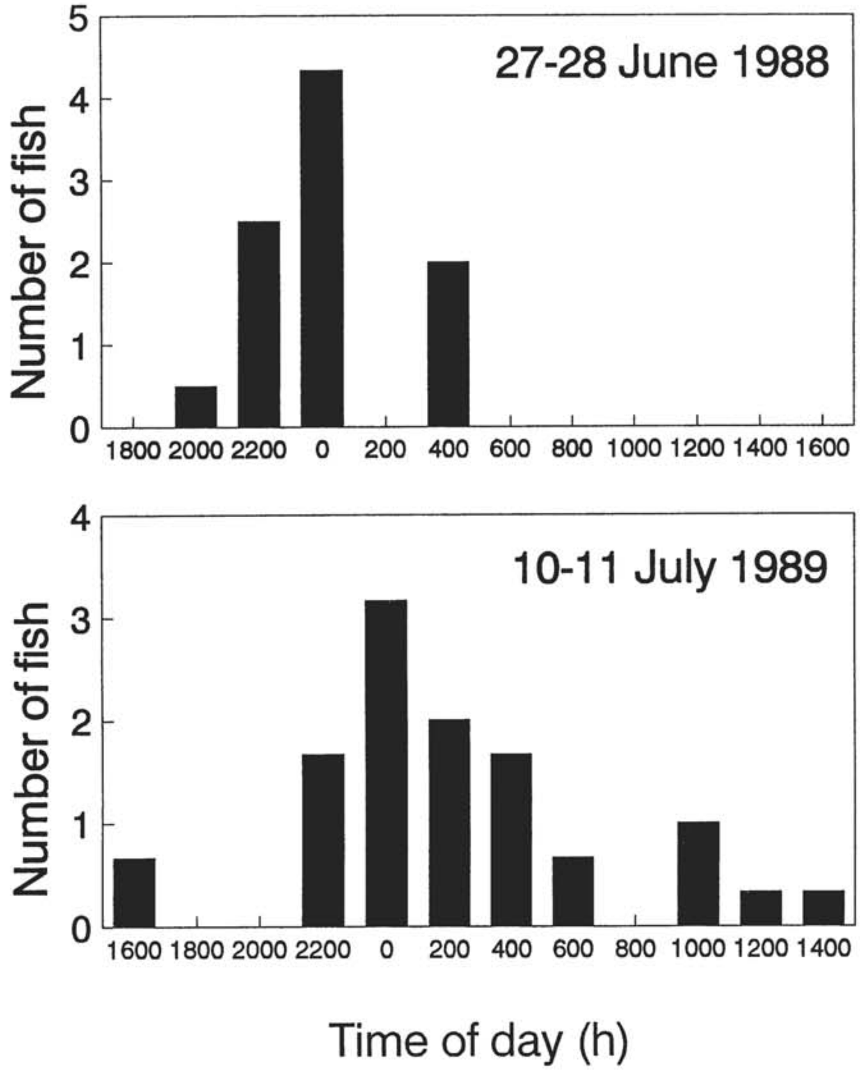

FIG. 4.—Catch per effort of madtoms collected by seining plotted against collection time. Results were standardized to 10-min collections

studied in this fashion is *Noturus eleutherus*; proportions of baetid mayflies in the gut of this species exceeded those in the environment, perhaps due to the nocturnal activity of these mayflies (Starnes and Starnes, 1985).

The word "preference" is used to describe the consumption of any taxa in a proportion higher than that found in the environment. In our study also, baetids were preferred—they were more abundant in madtom stomachs than in substrate samples. Only in March 1989 were baetids not eaten; at this time of year, these mayflies metamorphose into adults and leave the river. In addition to Baetidae, other preferred taxa were Chironomidae and Simuliidae. Simuliidae tend also to be nocturnally active (Waters, 1972).

Even though drifting taxa were selected, we are not suggesting that margined madtoms take prey from the drift. All evidence indicates that madtoms, including *Noturus insignis,* feed directly from the benthos (Bowman, 1932, 1936). Ictalurid catfishes detect food with

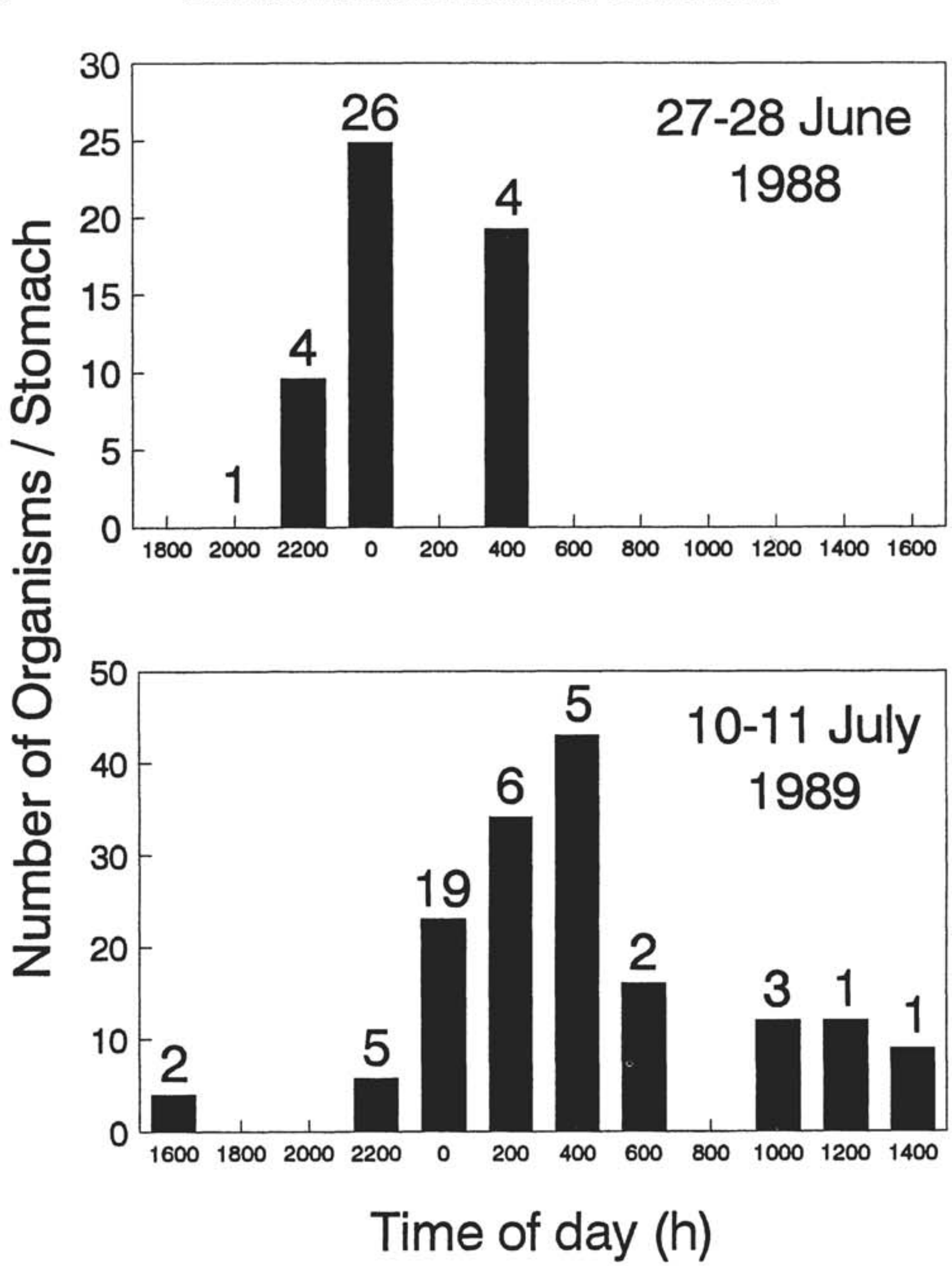

FIG. 5.—Mean number of organisms per madtom stomach vs. the time period madtoms were collected. Number of individuals is indicated over each bar

sensory barbels (Alexander, 1965), using tactile and olfactory cues, and usually feed on the bottom at night. Margined madtoms in both 24-h collections were most active, according to catch per effort data, near midnight. Locomotory activity levels increased after dusk (pers. observ.) as is common for most species of madtoms. Frequently, diurnal seine collections yielded fewer individuals than did nocturnal collections at the same location.

Our feeding activity data agree well with those for other madtom species. Robison and Harp (1985) observed that *Noturus lachneri* began feeding 20–90 min after sunset; ephem-

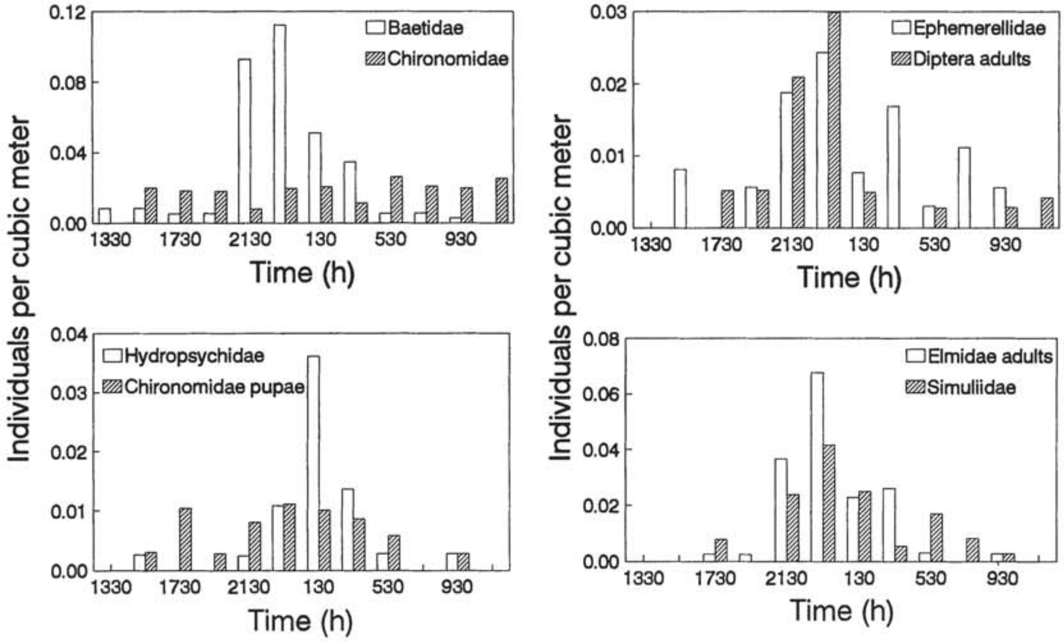

FIG. 6.—Potential prey taxa collected from the drift netting every 2 h vs. collection time. Numbers of individuals were standardized to volume of water flowing through drift nets

eropterans and chironomids were the most common food items. Chironomids were a major food source during spring, summer and autumn for *N. lachneri* (Robison and Harp, 1985), as well as for *N. insignis* in this study. Clark (1978) concluded that *N. leptacanthus* Jordan feeds nocturnally because catch rates in trap nets during the day were significantly lower than catch rates at night. Mayden *et al.* (1980) showed that *N. albater* Taylor collected between 2100–2300 h had full stomachs with little evidence of digestion, though they did not report data on any madtoms collected during the day. Curd (1960) and Taylor (1969) stated that madtoms feed primarily at night. There are some contradictory data for two madtoms. Miller (1984) found that *N. munitus* Suttkus and Taylor had fresh food in their stomachs during the day. Burkhead (1983, as reported in Simonson and Neves, 1992) reported no diel variation in diet or stomach fullness for *N. gilberti* Jordan and Evermann.

Smaller madtoms eat smaller prey, an indication of gape-limited predation. For all dates, the size of prey eaten was significantly different from those of medium and large fish ($P < 0.05$). There was no difference in prey size between medium and large madtoms on 27 June 1989 and 23 August 1989, as there was on other dates. On both days the number of individuals in these size classes was low, reducing the power of the test (Table 1).

Size-selective predation explains some the results of the taxon preference study. Some taxa not selected, perlid and gomphid larvae, are on the larger end of the size spectrum for benthic organisms and may be too large for madtoms. Other taxa that are nocturnally active but underrepresented in the diet may be so for different reasons. Elmidae beetle adults have a hard exoskeleton that could make digesting them difficult, whereas the taxa selected by the madtoms all have relatively soft exoskeletons. The mayfly families Ephemerellidae, Heptageniidae and Oligoneuridae are all larger members of the prey community. Ephemeridae burrow into the substrate and are probably inaccessible to madtoms. Moreover, even though members of a taxon may be nocturnally active, if they are in the drift instead of the substrate, they are not preyed upon by madtoms.

Page and Swofford (1984) hypothesized that prey-size distributions in lotic systems were responsible for the evolutionary trend toward smaller body sizes in darters. Testing this hypothesis with darters feeding on macroinvertebrates, Rakocinski (1991) found that large fish had a less optimal diet than did small fish. With the large abundance of small prey items at his study sites, small fish were able to feed more efficiently than large fish; prey as large as the small darters' maximum gape were available. Larger darters did not have enough large prey to maximize food collection vs. energy use. This hypothesis for the evolution of small-sized taxa could be applied to *Noturus*; it contains the smallest members of the family Ictaluridae. For all sizes of catfishes, the nocturnal life history is probably a result of the lower risk of predation while actively feeding. As Milinski (1986) stated, with foraging comes more visible movements and lessening of vigilance for predators. These can be minimized by feeding at night.

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